The effects of feeding sericea lespedeza hay on growth rate of goats naturally infected with gastrointestinal nematodes

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The effects of feeding sericea lespedeza hay on growth rate of goats naturally infected with gastrointestinal nematodes[1]

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ABSTRACT: Goat production is increasing in the United States due to high ethnic demand, but infection with gastrointestinal nematode (GIN) parasites is a major constraint to the industry. Increasing GIN resistance to chemical anthelmintics worldwide has led to the development of alternative control strategies, including use of forages containing condensed tannins (CT). An experiment was designed using infected and dewormed male kids (Kiko × Spanish, 6 mo old, 18.9 ± 3.25 kg) fed diets containing 25% concentrate and either 75% sericea lespedeza [SL; *Lespedeza cuneata* (Dum-Cours.) G. Don], a high CT forage (87 to 181 g of CT/kg), or 75% bermudagrass [BG; *Cynodon dactylon* (L.) Pers.] hay (n = 10/treatment). The kids were weighed every 14 d, and fecal and blood samples were taken weekly for fecal egg counts and packed cell volume determination, respectively. Fecal cultures were processed every 14 d to determine CT effect on larval development. At slaughter, adult GIN were collected from the abomasum and small intestines for counting and speciation. Blood samples were also analyzed for plasma urea-N, and ruminal VFA and pH were determined. The infected SL-fed kids had consistently lower ($P < 0.05$) fecal egg counts than the infected BG goats throughout the trial and greater ($P < 0.05$) packed cell volume beginning by d 77. Average daily gain was greater ($P < 0.001$) in kids fed SL- than BG-based diets, regardless of infection status (104.3 ± 5.0 and 75.5 ± 4.8 g/d, respectively). Total VFA and acetate concentrations were greater ($P < 0.001$) in the BG- than in SL-fed goats, whereas propionate levels were unaffected by diet. Acetate:propionate ratio ($P = 0.01$) and plasma urea-N ($P = 0.03$) levels were greater in BG-fed goats, whereas rumen pH was greater ($P < 0.001$) in the SL-fed goats. Feeding SL hay can reduce GIN infection levels and increase performance of goats compared with BG hay.

Key words: gastrointestinal nematode, goat, growth, sericea lespedeza

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INTRODUCTION

Infection with gastrointestinal nematodes (**GIN**) is an economic burden to production of sheep and goats in the United States. Hemonchosis, caused by blood-feeding activity of barber pole worms (*Haemonchus contortus*), can result in production losses and even death in untreated animals (Miller, 1996; Hoskin et al., 2002). The problem is particularly severe in the southeastern United States, where warm, moist climatic conditions are ideal for growth of GIN larvae on pasture (Miller, 1996). Frequent use of broad-spectrum anthelmintics has greatly increased prevalence of anthelmintic resistance in GIN worldwide (Waller et al., 1996; Bath, 2006), including the southern United States (Terrill et al., 2001; Mortensen et al., 2003).

An alternative approach for suppression of GIN infection is feeding or grazing forages containing condensed tannins (**CT**; Niezen et al., 1995; Min et al., 2004), including sericea lespedeza [**SL**; *Lespedeza cuneata* (Dum-Cours.) G. Don; 87 to 181 g of CT/kg,

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Terrill et al., 1989]. This forage is well-adapted to clay and loam soils in the southern United States (Hoveland et al., 1990), growing well on acidic, low-P soils where most legumes grow poorly (Joost and Hoveland, 1986; Joost et al., 1989). In studies with sheep (Lange et al., 2006) and goats (Shaik et al., 2004, 2006; Terrill et al., 2007), lower fecal egg counts (**FEC**) and GIN worm burdens were reported when feeding SL compared with bermudagrass [**BG**; *Cynodon dactylon* (L.) Pers.]. Shaik et al. (2006) reported an 80% drop in FEC in SL-fed goats relative to BG-fed goats 1 wk after initial hay feeding. The CT forages also can have nutritional as well as anthelmintic benefits to the animal (Terrill et al., 1992a; Waghorn et al., 1994; Waghorn and Shelton, 1997). Molan et al. (1999) suggested that feeding CT-containing forages increases rumen bypass protein, thereby counteracting protein loss due to GIN infection. Our objective was to determine the effect of feeding sun-dried SL on growth rate and GIN infection in young goats.

MATERIALS AND METHODS

All animal procedures used in this study were approved by the Fort Valley State University Institutional Animal Care and Use Committee.

Experimental Design and Protocol

A confinement feeding trial with 40 intact Kiko × Spanish male kids (6 mo old, 18.9 ± 3.2 kg) was conducted at the Fort Valley State University Agricultural Research Station, Fort Valley, Georgia. The goats acquired a natural GIN infection grazing (continuously stocked, 4 goats/acre) on pasture consisting primarily of the summer perennial grasses BG and bahiagrass (*Paspalum notatum* Flugge) for 56 d before moving to confinement in a covered barn with concrete floor pens for a 98-d feeding trial beginning at the end of August 2006. After a 21-d adjustment period, in which all animals were fed BG hay and a 16% CP commercial goat feed (Goat Chow, Purina Mills, St Louis, MO), goats were stratified by weight and FEC and randomly assigned to 8 pens (5 goats/pen). The area of each pen was 9.3 m^2, with similar temperature and sunlight conditions. The pens of animals were randomly assigned to 2 dietary treatments consisting of 75% hay [SL (CT) or BG (no CT)] and 25% concentrate (as-fed basis). The concentrate portion of each ration was formulated to balance the diets for CP and energy (Table 1). The treatment diets were then fed to 2 groups of GIN-infected and 2 groups of dewormed kids in a 2 × 2 factorial arrangement. After assignment to treatment diets, animals in the dewormed groups (20 animals in 4 pens) were treated on 2 consecutive days with a combination of levamisole (12 mg/kg of BW, Agri Laboratories Ltd., St. Joseph, MO), moxidectin (0.4 mL/kg of BW, Fort Dodge Animal Health, Wyeth Pharmaceuticals, Madison, NJ), and albendazole (20 mg/kg of BW, Pfizer Animal Health, Exxon, PA), after which the treatment diets were begun. Kids were initially fed at 4% of BW daily, with feed offered and orts recorded and adjustments made daily to allow 10% feed refusal. Water was available to animals for ad libitum intake.

Hay and Supplement Analysis

Proximate analysis procedures were based on AOAC (1990) protocols. Samples of SL and BG hays and the supplements were ground to pass a 1-mm screen using a Cyclotec sample mill (Foss, Eden Prairie, MN) and analyzed for N, GE, ADF, NDF, and fat content. Nitrogen analysis was completed using a carbon nitrogen analyzer (Vario Max, Elementar Americas Inc., Mt Laurel, NJ), with CP calculated as N × 6.25 (AOAC, 1990). Neutral detergent fiber and ADF were analyzed by sequential NDF-ADF analysis (Van Soest and Robertson, 1980) using filter bag technology (Vogel et al., 1999) and an ANKOM$^{200/220}$ Fiber Analyzer (Ankom Technology, Macedon, NY). Gross energy was analyzed using the IKA Calorimeter System (C2000; Mandel Scientific Company Inc., Guelph, Ontario, Canada), and fat content was analyzed using the Soxtec System (HT 1043) Extraction Unit (Tecator Inc., Herndon, VA). Extractable, protein-bound, and fiber-bound CT content of the hays were determined by the Terrill et al. (1992b) butanol-HCl method using purified SL CT as the standard (Terrill et al., 1990). All forage quality constituents are expressed on a DM basis (Table 2).

Sampling and Analysis Procedures

Goats were weighed every 14 d. At the end of the feeding experiment, animals were transferred to the Fort Valley State University meat processing plant and held overnight without feed but with access to water only in preparation for slaughter. Goats were weighed before slaughter to determine the shrink weight due to feed withdrawal. Blood samples were collected via jugular venipuncture into BD Vacutainer tubes (4 mL)

Table 1. Ingredients of supplements (25% of feed offered) used to balance the protein and energy content of sericea lespedeza (SL) or bermudagrass (BG) hay rations fed to growing goats

Supplement ingredients (DM basis)	BG ration	SL ration
	% of DM	
Corn	61.0	63.0
Soybean meal	31.0	28.2
Poultry fat	4.0	4.4
Trace mineral salt[1]	2.0	2.2
Vitamin premix[2]	2.0	2.2

[1]Contained >12% Zn, 10% Mn, 5% K, 2.5% Mg, 1.5% Cu, 0.3% I, 0.1% Co, and 0.02% Se.

[2]Contained 2,000,000 IU of vitamin A, 400,000 IU of vitamin D_3, and 230 IU of vitamin E/kg.

Table 2. Chemical composition of sericea lespedeza (SL) and bermudagrass (BG) hays and supplemental feeds used to balance the protein and energy content of experimental diets fed to growing goats

Items	SL hay	BG hay	SL supplement	BG supplement
	% of DM[1]			
OM	95.9 ± 0.05	95.4 ± 0.34	94.9 ± 0.004	95.1 ± 0.23
NDF	46.7 ± 0.23	73.7 ± 0.33	26.5 ± 5.30	29.3 ± 3.48
ADF	30.6 ± 0.50	34.6 ± 0.40	4.1 ± 0.72	4.1 ± 0.30
Ether extract	1.6 ± 0.04	1.4 ± 0.003	6.1 ± 0.37	8.6 ± 1.77
CP	12.5 ± 0.17	11.3 ± 0.01	22.0 ± 0.13	21.8 ± 0.15
GE, Mcal/kg of DM	4.2 ± 0.19	4.0 ± 0.13	4.3 ± 0.04	4.2 ± 0.25

[1]Average of duplicate samples ± SD.

containing EDTA (VWR Scientific, West Chester, PA) every 7 d throughout the trial and at exsanguination for plasma urea-N (**PUN**) determination using the urease-Berthelot procedure (procedure no. 640) at 570 nm (Fisher Diagnostics, Middleton, VA). Rumen fluid was collected at time of slaughter. After pH measurement, the fluid was strained through 8 layers of cheesecloth, acidified with 1% (vol/vol) of 3.6 *M* H_2SO_4, and stored frozen until processed for VFA and NH_3-N analyses. Frozen rumen fluid was thawed in the refrigerator overnight. Aliquots of rumen fluid were centrifuged at 10,000 × *g* for 10 min, and a portion of supernatant was collected for NH_3-N analysis. Another portion (5 mL) was left to stand on ice for 30 min after addition of 1 mL of 5% *m*-phosphoric acid and then centrifuged at 10,000 × *g* for 10 min. The supernatant was used for VFA analysis as described by Goetsch and Galyean (1983) using a Hewlett-Packard 5890 gas chromatograph (Hewlett-Packard Company, Palo Alto, CA) with packed glass column (Supelco 15% SP-1220/1% H_3PO_4 on 100/120 chromosorb WAW; Supelco, Bellefonte, PA). Rumen NH_3-N concentration was determined using the phenol-hypochlorite assay for NH_3 adapted from Broderick and Kang (1980). Plasma urea-N and rumen NH_3-N assays absorbance values were determined using a Shimadzu (Model UV-2401 PC) Ultra Violet-Visible Range Recording Spectrophotometer (Shimadzu Scientific Instruments Inc., Columbia, MD).

Parasitology Techniques

Blood and rectal fecal samples were collected every 7 d for packed cell volume (**PCV**) and FEC determination, respectively. All FEC determinations were made on fresh feces. Eggs per gram of feces were counted using a modified McMaster procedure (Whitlock, 1948), and PCV was determined using a Marathon 6K microhematocrit centrifuge and reader (Fisher Scientific, Pittsburgh, PA). Fecal cultures were prepared every 14 d on pooled samples from each GIN-infected treatment group using a modified Baermann's procedure as described by Terrill et al. (2004). Slightly crushed, whole fecal pellets (10 g) were moistened with distilled-deionized water, placed in a small plastic cup, covered in cheesecloth, inverted, and suspended over water in a second plastic cup, creating a small moisture chamber for each sample (Terrill et al., 2004). After 14 d at room temperature, additional water was added to the second cup to allow the infective larvae to wriggle out of the feces and settle to the bottom of the cup, excess water was removed by aspiration, and the larvae were retrieved, stained with iodine, and counted using a Swift M4000-D light microscope (Swift Optical Instruments, San Antonio, TX) to determine the type of larval infection present throughout the trial. The percentage of *H. contortus* larvae present and percentage of total larvae recovered were calculated using the following formula:

$$\% \text{ larval recovery} = [(\text{larvae/g})/(\text{eggs/g})] \times 100.$$

Adult GIN from abomasum and small intestines were recovered, counted, and identified to species using the procedures described by Shaik et al. (2006). The abomasum and small intestines for each animal were opened, and the contents were washed into plastic buckets, brought up to 3 L with water, mixed thoroughly, and then subsampled twice (2 aliquots of 150 mL each). The adult GIN were preserved by adding 100 mL of 10% buffered formalin solution (Sigma-Aldrich, St. Louis, MO) to each container. The GIN were then recovered and counted using a Leica Zoom 2000 phase contrast microscope (Leica Microsystems Inc., Chicago, IL).

Statistical Analysis

Fecal egg count, PCV, PUN, and ADG data were analyzed as a repeated measures analysis in a completely randomized design with a 2 × 2 factorial arrangement of treatments using the mixed model procedure of SAS (SAS Inst. Inc., Cary, NC). Because larval cultures were made from pooled fecal samples for each treatment group, percentage of larval recovery and percentage of *H. contortus* in recovered larvae data were not subjected to statistical analysis. These data are presented as arithmetic means ± SD from 2 replicates per treatment group. Data collected at slaughter (rumen, blood parameters, adult GIN data) were analyzed as a completely randomized design with a 2 × 2 factorial arrangement of treatments using the GLM

procedure of SAS. The FEC and adult GIN data were log-transformed before statistical analysis to normalize the data. When treatment effects were different at $P < 0.05$, means were separated using LSD test. Fecal egg count and adult GIN data are reported as least squares means, with statistical inferences based upon log-transformed data analysis.

RESULTS AND DISCUSSION

Feed Analysis

The chemical composition of the experimental feeds is shown in Table 2. Although the feed composition data were not analyzed statistically, fiber concentrations (NDF and ADF) for BG hay were greater than for SL hay. Analysis of the supplements showed CP values of 21.8 ± 0.15% for the BG diet and 22.0 ± 0.13% for the SL diet. Extractable, protein-bound, fiber-bound, and total CT were 1.35 ± 0.049, 4.68 ± 0.085, 0.44 ± 0.007, and 6.47 ± 0.134 for SL hay and 0.0, 0.29 ± 0.019, 0.53 ± 0.009, and 0.82 ± 0.028 for BG hay, respectively.

Intake and Growth

Total DMI was not affected by diet × infection level interaction ($P = 0.48$) or infection level alone ($P = 0.26$) but was greater ($P = 0.02$) for the SL-fed groups than the BG-fed goats (Table 3). The differences in total DMI were a result of greater ($P = 0.02$) quantities of hay being consumed by the SL groups (4.94 ± 0.33 kg/d, pen basis) compared with the BG animals (3.25 ± 0.33 kg/d, pen basis). All the pens were fed the same amount of supplement. Intake of OM followed the same pattern as DMI. There was no diet × infection status interaction ($P = 0.48$) or infection status effect ($P = 0.26$) on total OM intake, but diet type affected ($P = 0.02$) total OM intake due to greater ($P = 0.02$) SL hay OM intake.

The weights of the goats at the beginning of the trial were similar but differed due to dietary treatment at the end of the experiment (Table 3). Final weights were not affected by parasite infection status ($P = 0.35$) or diet × infection status interaction ($P = 0.63$) but were greater ($P = 0.01$) for SL-fed than BG-fed goats (29.2 ± 0.91 and 25.9 ± 0.88 kg, respectively). Average daily gain was not affected by infection status ($P = 0.33$) or diet × infection status interaction ($P = 0.21$), and there were no time effect ($P = 0.21$), time × diet ($P = 0.17$), time × infection status ($P = 0.87$), or time × diet × infection status ($P = 0.26$) interactions, but ADG was influenced by diet ($P = 0.003$; Figure 1). By d 45 of the trial, SL-fed goats had greater ($P = 0.002$) ADG than the BG-fed goats, and they were greater ($P < 0.001$) over the whole trial as well (104.3 ± 5.0 and 75.5 ± 4.8 g/d, respectively, for SL-fed and BG-fed goats). This may be explained by the fact that goats fed the SL diet had greater hay DMI, which consequently increased the OM intake and the nutrient intake, resulting in increased growth weight in SL-fed kids. Sericea lespedeza is a perennial, warm-season legume. Legumes are usually more digestible than grasses, therefore allowing more nutrients to be available to use for growth (Goering et al., 1991).

Table 3. Feed intake, BW, and ruminal pH and concentrations of VFA and NH_3-N of infected and dewormed goats fed sericea lespedeza- and bermudagrass hay-based diets

	Bermudagrass diet		Sericea lespedeza diet		
Item	Infected	Dewormed	Infected	Dewormed	SEM
Intake, kg/d (pen basis)					
Total DM	4.10[b]	4.34[b]	5.43[a]	6.39[a]	0.46
Hay DM	3.37[b]	3.13[b]	4.45[a]	5.42[a]	0.46
Supplement DM	0.97	0.97	0.97	0.97	—
Total OM	3.91[b]	4.15[b]	5.20[a]	6.12[a]	0.44
Hay OM	2.99[b]	3.21[b]	4.27[a]	5.20[a]	0.44
Supplement OM	0.93	0.94	0.92	0.92	—
Initial BW, kg	18.5	18.9	18.4	19.7	1.1
Final BW, kg	25.6[b]	26.2[b]	28.3[a]	30.2[a]	1.3
Rumen fluid pH	6.17[b]	6.22[b]	6.71[a]	6.56[a]	0.069
NH_3-N, m*M*	9.3	9.5	9.4	11.0	1.5
Total VFA, m*M*	93.5[a]	91.6[a]	65.1[b]	78.1[ab]	3.3
	mol/100 mol				
Acetate	68.2[a]	68.3[a]	61.1[b]	62.0[b]	0.78
Propionate	20.0	19.3	18.8	19.2	0.36
Butyrate	7.51[b]	7.93[b]	10.9[a]	11.3[a]	0.42
Isobutyrate	1.31[b]	1.35[b]	2.67[a]	2.19[a]	0.12
Valerate	0.94[b]	0.96[b]	1.89[a]	1.59[a]	0.096
Isovalerate	2.04[c]	2.11[c]	4.53[a]	3.63[b]	0.216
Acetate:propionate	3.42[a]	3.56[a]	3.25[b]	3.23[b]	0.092

[a–c]Within a row, means without a common subscript letter differ ($P < 0.05$).

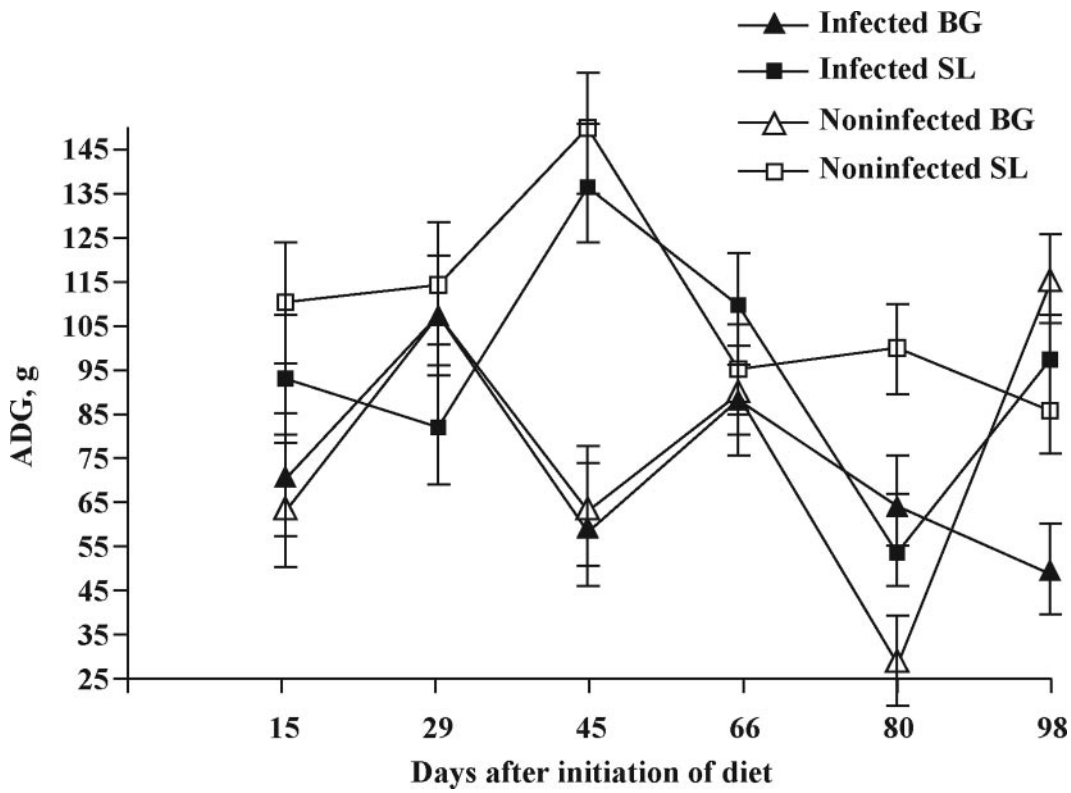

Figure 1. Effect of forage type (sericea lespedeza, SL; bermudagrass, BG) and infection status (infected or noninfected, dewormed) on ADG of growing goats (least squares means ± SEM).

Terrill et al. (1989) reported greater intake and DM digestibility in sheep fed fresh-frozen and sun-dried forage of low (87 g/kg) CT types of SL compared with high (181 g/kg) CT cultivars. Condensed tannins in birdsfoot trefoil (*Lotus corniculatus*) have been reported to bind to protein in the rumen, reducing protein solubility and increasing the flow of essential AA to the small intestines, increasing their availability for growth (Waghorn and Shelton, 1997). Niezen et al. (1995, 1998) reported that nondewormed lambs grew much better on sulla (*Hedysarum coronarium*), a CT-containing forage, compared with alfalfa (*Medicago sativa*), a non-CT forage.

After overnight feed withdrawal, animals uniformly lost approximately 7% of their original live weight. No treatment effects were observed. Feed withdrawal during preslaughter holding is a common practice to decrease gut fill and avoid gastrointestinal rupture during evisceration (Sheridan, 1998). Fecal material is a major source of carcass contaminants at the abattoir (Sheridan, 1998).

Plasma Metabolites and Rumen Fluid Analysis

Rumen pH (Table 3) was greater ($P < 0.001$) in the SL-fed (6.64 ± 0.05) compared with BG-fed goats (6.20 ± 0.05) but was not affected by parasite infection status ($P = 0.47$) or diet × infection status interaction ($P = 0.16$). Typically, legumes have a greater concentration of protein and Ca^{2+} than grasses and thus have better buffering capacity (Van Soest, 1988). Ruminal pH most often relates to the total VFA concentration in the rumen. Greater VFA production generally leads to relatively lower pH (Baldwin and Allison, 1983).

Total VFA concentrations were not affected by diet × infection status ($P = 0.12$) or infection status alone ($P = 0.25$) but differed ($P < 0.001$) due to diet (71.6 ± 3.3 m*M* for SL-fed and 92.6 ± 3.3 m*M* for BG-fed goats). Acetate concentration and acetate:propionate ratio were not affected by infection status ($P = 0.53$, $P = 0.54$) or diet × infection status ($P = 0.64$, $P = 0.42$). The BG-fed groups had greater ($P < 0.001$) acetate concentrations (63.3 versus 44.2 m*M*) and greater ($P = 0.011$) acetate:propionate ratios (3.49 versus 3.24) than the SL-fed animals. There was no difference between dietary treatment in propionate concentrations ($P = 0.09$). The BG-fed kids had greater ($P < 0.001$) total VFA concentrations because of the increase in acetate concentrations. High-roughage diets tend to have more fiber-digesting microbes that produce acetate as a by-product of fermentation (Baldwin and Allison, 1983). High acetate levels in the BG groups also probably contributed to lower the pH in ruminal fluid of these animals. The greater acetate:propionate ratio for BG-fed goats was also due to their greater acetate concentration. Lower acetate:propionate ratio in SL-fed animals could help explain their greater growth rate, because propionate can be converted to glucose through gluconeogenesis.

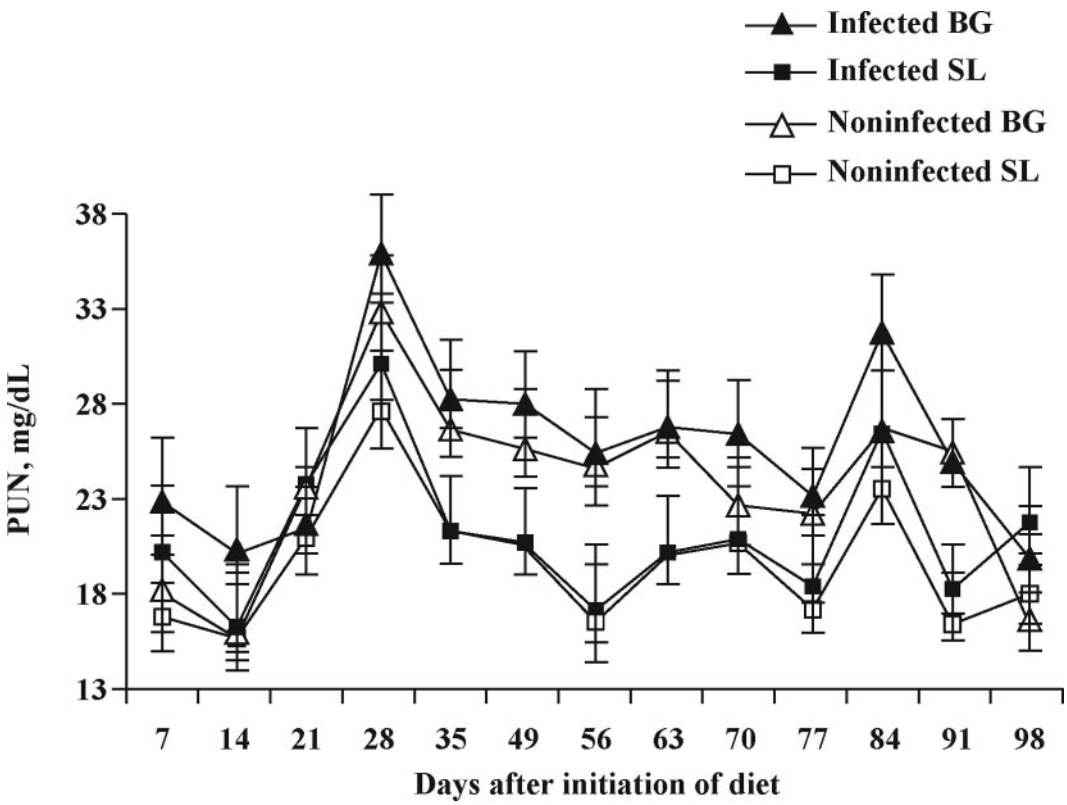

Figure 2. The effect of forage type (sericea lespedeza, SL; bermudagrass, BG) and infection status (infected or noninfected, dewormed) on the plasma urea-N (PUN) concentration of growing goats (least squares means ± SEM).

Branched-chain VFA (isovalerate and isobutyrate) had significant diet × parasite infection status interaction ($P = 0.03$, $P = 0.04$) and diet main effects ($P < 0.001$). Butyrate, isobutyrate, isovalerate, and valerate were greater ($P < 0.001$) in SL-fed animals than in the BG groups. Branched-chain VFA may arise from the degradation of branched-chain AA: valine, leucine, and isoleucine (Shazly, 1951). Greater pH may also promote a more diverse population of rumen microbes, leading to greater microbial activities, such as increased CP deamination by protozoa. It has been reported that greater protozoa activity may lead to greater branched-chain FA (Jouany, 1996).

Rumen NH_3-N was not affected by diet ($P = 0.57$), infection status ($P = 0.56$), or diet × infection status interaction ($P = 0.66$; Table 3), suggesting that protein degradation in the rumen was similar for the diets. Plasma urea-N was not influenced by infection status ($P = 0.25$) or diet × infection status interaction ($P = 0.86$), but there were time ($P < 0.001$) and time × diet effects ($P < 0.001$) on PUN levels (Figure 2). Goats fed the BG diets had greater ($P = 0.01$) PUN concentrations than SL-fed goats. Plasma urea-N at the beginning of the trial were not different, but by d 28, BG-fed kids had greater ($P = 0.03$) PUN levels than SL-fed animals. These differences were also observed for d 35 ($P = 0.002$), 49 ($P = 0.003$), 56 ($P = 0.003$), 63 ($P = 0.002$), 77 ($P = 0.005$), and 91 ($P < 0.001$), whereas, at sampling d 42, 70, and 84, PUN levels in BG-fed kids were similar to that of SL-fed kids. Plasma urea-N values were also similar after overnight feed withdrawal (BG group 18.3 ± 1.3 mg/dL and SL group 19.9 ± 1.3 mg/dL). Plasma urea-N concentrations are closely related to rumen NH_3-N and to AA deamination after absorption (Spires and Clark, 1979). Similar ruminal NH_3-N, but greater PUN, may indicate greater AA deamination with the BG-fed kids. Greater PUN concentrations in BG-fed goats show that AA are being used less efficiently by the BG kids. Legumes tend to have a more balanced AA profile than grasses, and with greater potential rumen bypass of CP due to the action of CT, the SL-fed kids apparently used the AA more efficiently for growth than BG-fed kids (Waghorn and Shelton, 1997). This may also help explain why SL kids grew faster than BG kids even though the 2 diets were balanced for energy and protein.

FEC

There were no time × diet ($P = 0.11$), time × infection status ($P = 0.06$), or diet × infection status ($P = 0.77$) effects on FEC, but the time × diet × infection status interaction was significant ($P = 0.046$; Figure 3). There was no effect of infection status on FEC ($P = 0.18$), but diet affected FEC, with reduced ($P = 0.02$) egg levels in SL-fed goats. There was a rapid initial

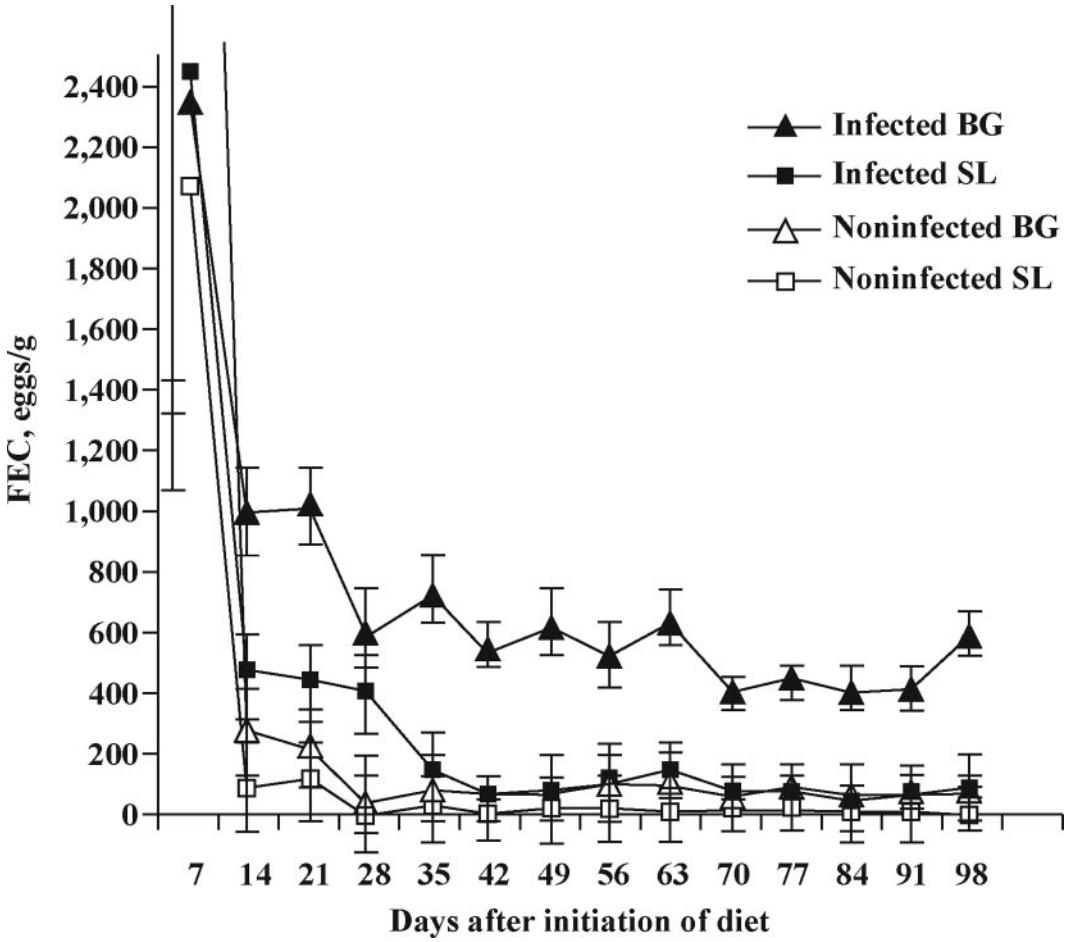

Figure 3. Effect of forage type (sericea lespedeza, SL; bermudagrass, BG) and infection status (infected or noninfected, dewormed) on the fecal egg count (FEC) of growing goats (least squares means ± SEM). Initial value for noninfected BG was too high to fit in the figure (5,766 eggs/g).

drop in egg count for all of the treatment groups, but FEC was lower ($P = 0.002$) for the dewormed SL kids than for all the other 3 groups by the second sampling date (d 14) and remained low throughout the rest of the experiment (Figure 3). The SL-infected group had lower ($P = 0.01$) FEC than the BG-infected goats by d 42, and these differences were then maintained throughout the remainder of the trial. The effect of reduced GIN infection levels in kids fed SL hay confirms recent reports with sheep and goats fed this forage in different dried forms (Lange et al., 2006; Shaik et al., 2006). Reduced FEC has been attributed to both direct (reduced fecundity, killing of adult worms; Shaik et al., 2006) and indirect (improved immune function due to greater absorption of AA; Niezen et al., 2002) effects. Internal parasites can be managed to some degree in lambs by feeding an increased level of supplement or forages high in protein, allowing the animal to tolerate greater parasite loads and still be productive (indirect effect; Knox et al., 2006). Shaik et al. (2006) reported a predominantly direct effect of SL hay on GIN in goats, with approximately 70% less adult *H. contortus* compared with animals fed BG hay. Lange et al. (2006) suggested that the effect of SL hay feeding on GIN in sheep was a combination of reduced fecundity and direct killing of the worms. Both direct and indirect effects against GIN infection appear to be occurring in the current investigation.

Packed Cell Volume

None of the time, diet, and infection status interactions were significant at $P = 0.05$ for PCV data (Figure 4). The diet ($P = 0.02$) and time ($P < 0.001$) effects were significant, but infection status had no effect ($P = 0.23$) on PCV values. The dewormed SL goats had greater ($P < 0.05$) PCV than the BG-infected group beginning at d 35 of the trial, whereas the SL dewormed animals were greater ($P < 0.005$) than either of the BG groups beginning with d 49 (Figure 4). The SL-infected kids had greater PCV than the BG dewormed group at d 77 ($P = 0.02$) and 98 ($P = 0.02$) of the study. Improved PCV could be due to reduced number of blood feeding adult nematodes in the abomasum or improved nutrition allowing the animals to replace lost blood cells more quickly (Miller and Horohov, 2006). Both effects may be occurring in the SL-fed kids, because these animals had lower FEC and likely had more efficient CP utili-

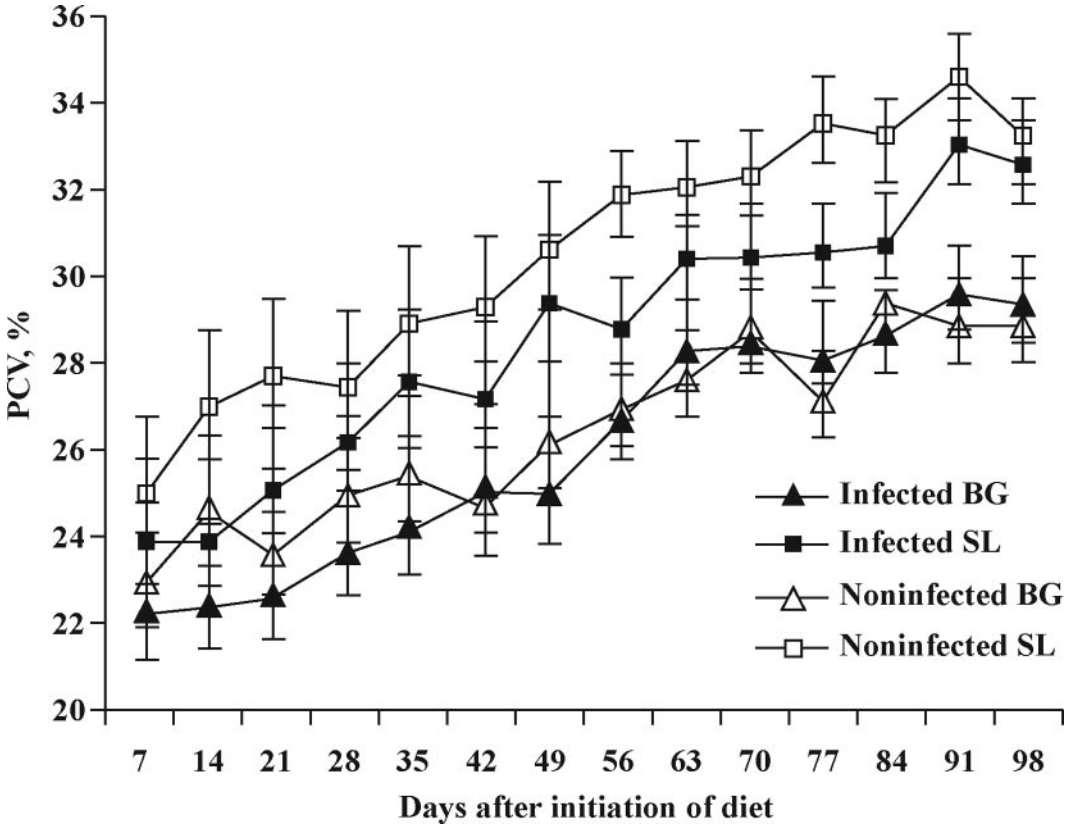

Figure 4. Effect of forage type (sericea lespedeza, SL; bermudagrass, BG) and infection status (infected or noninfected, dewormed) on the packed cell volume (PCV) of growing goats (least squares means ± SEM).

zation. Greater PCV has been reported for both sheep and goats fed SL compared with BG hay (Lange et al., 2006; Shaik et al., 2006).

Total Larval Development and H. contortus Larval Percentage in Fecal Cultures

The mean overall percentage of larval development (percentage of parasite eggs hatched and developed into larvae) in fecal cultures was greater in BG-fed than the SL-fed goats throughout the 98-d trial (116 ± 27 and 55 ± 34%, respectively). These results are supported by the work of Molan et al. (1999, 2002), who showed that CT extracts can disrupt the life cycle of nematodes by inhibition of egg hatching and larval development. Shaik et al. (2006) also reported lower percentage of larval development in goats fed SL hay compared with BG hay.

Throughout the trial period, there was an overall decrease in *H. contortus* as a percentage of total larvae recovered in pooled samples from the BG- and SL-infected animals. During the first 28 d after treatment diets were begun, *H. contortus* levels averaged 55 ± 0.7 and 71 ± 5.9% of the total larval population in fecal cultures from BG- and SL-infected goats, respectively. During the last 70 d of the trial, this trend was reversed, with BG- and SL-infected goats having 38 ± 7.6 and 13 ± 4.8% *H. contortus* larvae in fecal cultures. Reduction in percentage of *H. contortus* infection in control animals probably indicates a loss of some adult worms over time because of the length of the trial and the lack of reinfection with new larvae. Lower *H. contortus* larvae in SL-fed compared with BG-fed goats may indicate an effect of CT on egg or larval viability. Shaik et al. (2006) reported similar results in goats fed SL and BG hays.

Adult Nematodes

There were no significant diet ($P = 0.89$), infection status ($P = 0.17$), or diet × infection status interaction ($P = 0.55$) effects on total adult nematodes. For total abomasal worms, there were no diet ($P = 0.69$) or diet × infection status effects ($P = 0.60$); however, there was a significant effect of infection status ($P < 0.001$). Diet ($P = 0.87$), infection status ($P = 0.25$), and diet × infection status interaction ($P = 0.54$) all had no effect on total worms in the small intestine. The total worm numbers, particularly for the abomasal infections, were low in all treatment groups. Total adult worms and total abomasal and small intestinal worms, regardless of dietary treatment, were 394 ± 184 and 830 ± 171, 2 ± 15 and 70 ± 14, and 392 ± 179 and 760 ± 166 for noninfected and infected goats, respectively. Abomasal worms included *H. contortus*, *Teladorsagia circumcincta*, and *Trichostrongylus axei*, whereas all the small intestinal worms identified were *Trichostrongylus colubriformis*. All groups had a mainly *Trichostrongylus* infection by

the end of the trial. Presence of small intestinal, but essentially no abomasal nematodes, in the dewormed goats indicates possible anthelmintic resistance of *T. colubriformis*. Resistance of *T. colubriformis* to anthelmintic treatment has been reported for many parts of the world in both sheep and goats (Prichard, 1990; Sangster, 1999; Mortensen et al., 2003), and our data provide further evidence of this growing problem. Differential susceptibility to anthelmintic treatment by different GIN species has been reported in several studies reviewed by Sangster (1999).

Although the differences were not significant, abomasal worm numbers were lower in SL-fed than BG-fed infected goats (54 ± 20 and 85 ± 19, respectively). Recently, Min and Hart (2003) showed that GIN were controlled in Angora does grazed on *L. cuneata* (52 g of CT/kg of DM) in spring and summer, but not when goats were grazed on control forages (crabgrass-tall fescue; 2.0 g of CT/kg of DM). Tracer goats that grazed *L. cuneata* had a 76% reduction in total adult worm burdens compared with the control animals. The *L. cuneata* diet resulted in a 94% reduction in *H. contortus* adults, a 100% reduction in *Teladorsagia* spp., and 45% lower numbers of *Trichostrongylus*. Similar results were reported by Shaik et al. (2006) for goats fed SL compared with BG hay. *Hemonchus contortus*, *Teladorsagia circumcincta*, and *T. colubriformis* adults were reduced by approximately 70, 30, and 40%, respectively, in the goats fed the SL hay, with a greater effect on female than male worms. There was no consistent effect on male and female worms in the current investigation. Lack of a significant diet effect on abomasal worms in the current investigation can be attributed to overall low infection levels, perhaps due to the extended length of the trial contributing to increased die-off of the adult worms.

In conclusion, feeding SL hay to goats had both nutritional and antiparasitic advantages compared with BG hay. As a low-input crop, SL hay appears to have potential as an inexpensive, environmentally friendly alternative to chemical deworming. Additional research with SL hay is warranted to determine the optimum concentration in the diet needed to maximize nutritional and antiparasitic benefits for goats and possibly other livestock species, both in confinement-feeding and as a supplement in pasture-grazing systems.

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